Studying the mechanisms of sub-mm wave emission from plasma due to two-stream instability of relativistic electron beam

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Studying the mechanisms of electromagnetic wave emission from magnetized plasma due to the development of two-stream instability of a high-current relativistic electron beam (REB) is considerably important. The two-stream instability is a fundamental process occurring in both cosmic and laboratory plasmas. In laboratory experiments, the beam-plasma interaction allows one to generate high-power sub-mm waves with the promptly varying frequency[1] that is important for practical applications. In this paper, we present the novel results on studying the mechanisms of sub-mm wave emission produced in a REB-plasma system as a result of the two-stream instability development.

Experimental investigations are carried out at the GOL-PET device. In these experiments, the high-power REB (0.7 MeV/ 20kA/ 10 μs) is transported through a plasma column of 2 m length with the density $n_p = (0.5 \div 2)\times 10^{15}$ см$^{-3}$ which is confined in corrugated magnetic field with average induction B_m= 4.2 T and corrugation factor 1.5. We have measured the temporal dynamics of the radiation spectra by a 8-channel polychromator with semiconductor diodes for the frequency range 0.1÷0.5 THz and by an additional 2-channel system of cryogenic sensors for 0.5÷0.9 THz one. It is found that the high level of spectral power density of the radiation is mainly concentrated in two clearly distinct regions of spectrum. For the plasma with density near 1×10^{15} см$^{-3}$, the first frequency region is located from 0.25 up to 0.35 THz, the second one – from 0.6 up to 0.8 THz. The emission power in these regions depends essentially on the radial profile of the plasma density in the cross section of the plasma column. This profile is measured by Thomson scattering system during the beam injection in eight points over the plasma column diameter.

We have compared the experimental results with existing theoretical models describing the conversion of the beam-driven plasma oscillations into electromagnetic radiation for the typical conditions of our experiments. It is found that for the first frequency region the observed emission can be interpreted by the linear mode conversion[2] of the upper-hybrid branch of plasma oscillations to the electromagnetic radiation in the regions of strong plasma density gradients. For the second frequency region the emission is occurred due to merging of these oscillations at a high level of plasma turbulence[3].

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